INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI
SHORT ABSTRACT OF THESIS

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Programme of Study : **Ph.D.**

Thesis Title:
Studies on Biodegradation of Bioplastics under Composting Conditions and its Ecotoxicology Impact on Crop Sustainability

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Thesis Submitted to the Department/ Center : Department of Chemical Engineering

Date of completion of Thesis Viva-Voce Exam : 06/11/2020

Key words for description of Thesis Work : Poly(lactic acid) (PLA); Biodegradation; Composting; Ecotoxicological

SHORT ABSTRACT

The use of plastic products increases problems associated with waste disposal and management. Growing concerns related to environmental degradation has directed research towards the development of plastics that could undergo biodegradation. Biodegradable materials that are commonly present in the market are poly (lactic acid) PLA, polycaprolactone PCL, and poly(butylene adipate-co-terepthalate)], PBAT. Other examples include cellulose, protein, chitosan, gum arabic etc. PLA, a linear aliphatic polyester has significant potential to replace the conventional petroleum based plastics to overcome such disposal problem. Most of these plastics are specifically targeted towards packaging applications that may help to facilitate scrap collection for their composting. Collection of these scraps and commercial composting facilities are increasing day-by-day across the globe with increasing use of those biodegradable plastics. Plastic materials originating or produced from bio-sources like corn, starch, sugar etc., unlike conventional plastics originated from fossil-based sources, are known as bio-based plastics, and also called “plant-derived products”. Hence, plastics that biodegrade within a certain time period are said to be biodegradable plastics. Main motivation behind the current work is to understand and to observe the extent of biodegradation of biopolymer based biocomposites and blends under composting and natural soil conditions for development of a suitable biopolymer based composite with high biodegradability. This work also focused on biodegradation through biofilm formation. In this work, ASTM D5338-15 was followed for laboratory setup and standard protocol with a little modification for accessing percentage biodegardation. Indigenously built composting reactors were designed and built for the composting process with accordance to ASTM International D5338-15. PLA and PCL can be synthesized by polymerization of precursor lactic acid or its derivative lactide and monomer caprolactone respectively. Mixing optimized concentrations of biofillers (modified chitosan, modified gum, functionalized cellulose nanocrystals (CNC), cellulose microcrystalline (MCC)) and algae biomass with PLA and PCL enhanced plastic properties with biodegradibility. Hence, its percentage biodegradation and biodegradability tested under different environmental conditions. Biodegradation kinetics and percentage biodegradation of these blends and biocomposites revealed

modified chitosan of having higher rate of biodegradation than other tested samples. This was due to presence of nitrogen as amines in the chitosan, which lead to higher microbial assimilation of the biocomposite. For supporting this thought algae biomass with high nitrogen content was used as biofiller in PLA based biocomposites. It was found that it has increased the biodegradation rate of the bioplastic due to formation of high microbial colony growth and early attraction of microbes in the film surface during the degradation period than neat PLA making it more susceptible towards microbial assimilation at a much faster rate than rest of the filler used under composting environment. Thus, algal biomass can be used in PLA as well as in PCL based biocomposite for enhancing the biodegradation rate of the biopolymer under composting condition. PLA/PCL/MCC: 80/20/3 also showed higher biodegradation rate than neat PLA and neat PCL under composting environment. Under natural soil condition, it was found that both commercial PCL and our lab synthesized PCL got biodegraded under 180 days of time. It was also found that addition of certain biofillers slowers the rate of biodegradation in PLA based biocomposites under composting condition prepared for improving properties like mechanical strength and permeability. Another study demonstrated the plant growth study of potato (Solanum tuberosum L) on used (biopolymer biodegradation biomass) compost as fertilizer or growth substrate under controlled greenhouse condition. Molecular weight of the samples with biopolymer and without biopolymer was found to be 400 Da and 430 Da signifying zero uptake of any oligomers from the biopolymers. Despite of high pH of 7.8, the growth was good, assuming null effect of high pH on plant growth. Biodegradation of the polymers during the composting did not increase the conductivity of the tested growth medium which showed good growth in the potato plant with good salt uptake. This study revealed current understanding to identify the knowledge gaps and future research priorities related to biopolymers as well as biopolymers “nature-to-nature” sustainability. Future detailed analysis can reveal more details related to reuse of compost biomass after biopolymer biodegradation in more sustainable approach. Therefore, this doctoral thesis mainly focuses on the biodegradation study of PLA and PCL based biocomposites and blends under composting as well as in natural soil condition. Characterization of the test samples after biodegradation for better understanding and underlying a biodegradation mechanism with an assessment of biodegradation and summarizing up all the results for obtaining best material characterization is the main goal to enhance biodegradability of the test samples, which has been summarized in eleven different chapters with detailed explanation in subsequent sections of the PhD thesis.